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ABSTRACT

Questionnaires designed to identify and assess the views, beliefs, and opinions of university/college science faculty on the nature of science were sent to 318 randomly selected science faculty in the biological, physical, and earth sciences, and 23 prominent philosophers of science. Among the results of the study, it was found that both groups maintain the perspective that science is the process and product of a dynamic man-world interaction rather than the literalistic description of nature. It was also shown that scientists clearly favor the view that scientific laws are empirical generalizations over the view that they are confirmed theories or certain reports of inviolable relations. In contrast, the philosophers exhibit no significant preference between the first two views. (Author/MH)

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VIEWS ON THE NATURE OF SCIENCE AMONG COLLEGE SCIENCE FACULTY

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VIEWS ON THE NATURE OF SCIENCE AMONG COLLEGE SCIENCE FACULTY

Introduction

In science education the philosophy and history of science has established itself as a legitimate subject because science educators have recognized that an understanding of the nature of science is an integral part of becoming scientifically literate as a citizen (AAAS Guidelines: NSSE 59th Yearbook; Commission on College Physics). (In this paper reference to the philosophical, historical and sociological foundations, structure, and processes of science will be abbreviated by using the term 'nature of science'.)

Both education and sociology have barely touched the arena of empirical investigations in the sociology of scientific knowledge, particularly the sphere of philosophical viewpoints, categories of thought, presuppositions, norms, self-awareness of beliefs, perspectives and objectives of the scientist. Schmidt (1967) collected TOUS scores on "Iowa scientists" and compared their mean score with other groups ranging from students to teachers. Kimball (1967) constructed the Nature of Science Scale (NOSS), an instrument built from a collection of eight declarations based on the writings of some prominent philosophers and scientists. Kimball compared the views of science majors and philosophy majors who had graduated from two California schools. He found that the difference between the scientist group and the philosophy group was significant at the .01 level. West (1960) made a study of the idealogy of 57 academic scientists by means of personal interviews. Scientists' acceptance of six classical values of science (freedom in research, impartiality, suspension of judgment, absence of bias, accessibility of information, group loyalty) were investigated in an attempt to test experimentally portions of R. K. Merton's and B. Barber's schemes on the ethos of modern science. Ian Mitroff (1973) investigated the phenomenon of commitment to ideas and objectivity among 42 Apollo moon scientists through personal interviews. The results showed that the scientists felt that the notion of a purely objective, disinterested scientist was naive. The passionate, often irrational, adherence to ideas was more the norm for scientists who were bold and imaginative enough to propose theories regarding the moon-earth system.

The Problem

What are the views, beliefs, and opinions of university/college natural science faculty in the U.S. on the nature of science? What views are widely held; on what issues is there consensus? What differences in viewpoint or perspective exist between college scientists and philosophers of science? (The terms 'college scientists' and 'academic scientists' in this paper are used synonymously with 'college science faculty') What relationship, association, or correspondence can be found between college scientists' views on the nature of science and various demographic variables including area of science, type of educational institution where employed, highest academic degree attained, amount of study in the nature of science, extent of previous thought about issues in the criterion instrument, age, and geographical region? These questions defined the problem undertaken in this study.

Instrumentation and Methodology

The variables used in this study were: (1) demographic variables (as listed above); (2) dependent variables--views or perspectives concerning numerous aspects and dimensions of the nature of science, including description, growth of science, objectivity, confirmation of theories, aims of science, scientific laws, scientific models and others.

The criterion instruments by which the above variables were measured were two questionnaires. In the demographic questionnaire (see appendix A) the respondents marked appropriate categories of each variable. The second instrument, called Inventory of Views on the Nature of Science (IVNS), assessed the agreement or disagreement with statements in a multiple choice format. (see Appendix 2). IVNS contained 44 items, each focusing on a particular issue. The respondents could mark more than one response on a given item, and they could add their own response.

The construction of IVNS went through three stages. First, a pool of about 150 items covering 14 themes or general areas of the nature of science was created. The themes were defined and formulated by the investigators. The themes are as follows:

1. Facts and observations
2. Aims of science
3. Scientific laws
4. Scientific models
5. Theoretical terms
6. Scientific theories
7. Objectivity
8. Verification and falsification
9. Progress in science
10. Science and society
11. Presuppositions of scientists
12. Processes of sciencing
13. Characteristics of the scientific community
14. Science vs. other disciplines

Two pilot stages followed with construction of preliminary instruments, field testing, and revision.

A national sample of university/college science faculty in the biological, physical, and earth sciences was randomly chosen and the criterion instruments were administered by mail. The size of the sample was initially set at 800 science faculty and 60 prominent (estimation of the investigators) philosophers of science. The sample sizes were later reduced as information on death, retirement, leave of absence, etc. was obtained. To assure that the relative proportion of faculty in different fields of science in the sample was representative of the national proportions, the sample was stratified according to major areas (biological sciences, earth science, chemistry, physics).

After the individuals in the initial sample were selected, each 'area of science' group was divided in half. The first half of each group was sent Part 1 of IVNS, the second half was sent Part 2. IVNS was divided into two parts

because the estimated time required to fill out either part was 30-40 minutes. The entire questionnaire, however, was sent to the selected group of philosophers of science. Following the reception of the data, the samples were divided into three categories--(1) those who participated in the study and returned the questionnaires, (2) those who declined to participate but stated a reason for their non-participation, and (3) those who did not reply or participate in any way. Table 1 summarizes the numbers of scientists and philosophers falling into each category.

The first research question to be posed was: On what items of IVNS is a consensus among science faculty for one alternative shown? Since no universal standard for consensus on survey questions exists, the standard was set by the author in consultation with a test consultant, viz. consensus is shown if an item alternative is chosen by 50% or more of the respondents and no other alternative is chosen by more than 25% of the sample. The criterion for consensus also included the standard that if any item-alternative was chosen by 6 or fewer persons (about 4%), consensus for rejection was indicated.

Since respondents had the option of making multiple responses on an item in which they found two or more equally viable alternatives, tabulation of multiple responses in making frequency counts was handled by fractionizing the response. The fractionizing procedure was statistically compared with the procedure of randomly selecting one of a multiple response. No significant difference in the distribution of responses by the two tabulation procedures was found.

From the data collected, thirteen scales and two aggregate scales, each representing a broad viewpoint on different aspects of the nature of science, were formulated from the pertinent item-alternative statements which resulted in the highest internal consistency. Appendix 3 describes the thirteen scales and two aggregate scales of IVNS, delineates the item-alternatives that comprise each scale, and specifies the Cronbach α coefficient (KR20) for each scale. The item-alternatives are designated by a hyphenated number, the first being the IVNS item number and the second being the response number within the respective item. Some scales consist of two mutually exclusive perspectives, representing the extremes of the scale. In such cases they are designated by subheadings A and B, and the α coefficients for these subsets have also been calculated.

The responses to each item-alternative were recorded as a "1", "0", or blank depending on acceptance, rejection or no response to the statement. A scale score was the sum of all relevant item-alternative responses. It represented the extent of acceptance or rejection of the corresponding perspective.

The second research question posed was: What relationships are observed between perspectives within various topics if the nature of science and the selected demographic variables? This question was investigated by formulating a null hypothesis for each demographic variable and testing the hypothesis with a multivariate analysis of variance. The general form of the null hypothesis was stated as follows: Given the responding population of U.S. natural science faculty, there are no differences between the centroid matrices, whose elements are made up of scale means, as measured by the criterion instrument for the categories of each selected demographic variable.

TABLE 1

Participation Characteristics of the Survey Sample

Group	Area of Science										Philosophers of Science	
	Biology		Geoscience		Chemistry		Physics		Total			
	N	%	N	%	N	%	N	%	N	%	N	%
Participants	138	43	27	36	84	39	69	48	318	42	23	40
Persons declining to participate with a stated reason	20	6	7	9	19	9	4	3	50	7	5	9
Persons not replying	166	51	42	55	110	52	70	49	388	51	29	51
Total	324		76		213		143		756		57	

The third major research question in this investigation was: Are there single, dominant views among scientists concerning the chief aim of science, the nature of scientific laws, and the nature of scientific models? Views on these issues were assessed in the IVNS scales 3-10 (Part 1). This research question was answered by examining the relevant pairwise scale contrasts. The null hypothesis was stated in the following general form: Given the responding population of U.S. natural science faculty, there is no difference in each of the relevant pairwise contrasts on the chief aim of science (Scales 3-5), the nature of scientific law (Scales 6-8), and the nature of scientific models (Scales 9-10).

The fourth research question concerned the representation of points of view on the issues represented by the individual items of IVNS. The null hypothesis for each item of IVNS was stated as follows: There is no statistical association between the distribution of opinion and the categories of each demographic variable. These hypotheses were tested by a Pearson chi-square test of independence. The α level was set at .01.

Experimental Results

Since the results are manifold, only a few tables will be printed in this paper and results from two or more statistical analysis will be merged whenever possible in making conclusions. Tables 2 and 3 indicate the consensus items for Part 1 and 2 respectively. Tables 4 and 5 list the range, mean and s.d. of each scale for each vocational group and the results of the multivariate analysis of variance (MANOVA) on the independent scales and the simple analysis of variance (ANOVA) on the two aggregate scales (Scale II in Part 1; Scale 4 in Part 2). The analysis were repeated for each of the seven demographic variables. Significant univariate F values were found for groups in area of science on scale 3 (aim of science--theoretical) and scale 6 (scientific laws as empirical generalizations), for groups with varying study in the nature of science on scale II (relationship between the scientist and nature), for groups varying in extent of thought about issues in IVNS on scales 3 and 6, for age groups on scale 9 (scientific models as analogies) and scale 2 (Part 2) (objectivity).

Table 6 lists the pairwise contrasts of the minor scales (scales 3-10, Part 1) for the sample of academic scientists and philosophers of science. Table 7 shows the pairwise contrasts for groups within each area of science. Similar sets of contrasts were made for the other demographic variables.

The results of the individual IVNS items displaying significant differences in the distribution of opinion between groups of each demographic variable are shown in tables 8-24. The results indicate that few statistically significant relationships between items and demographic variables exist. Comparisons between science faculty and the philosopher group were the most frequently significant. On about a fourth of the 44 IVNS items significant differences at the .01 level were found; most occurred on items dealing with the nature of scientific theories. If "study in the nature of science" and "extent of thought about issues" are merged as one variable, then this variable is the next most interactive with views on the nature of science (IVNS items).

Table 2

Consensus Items for Part 1

Items	Responses 1	2	3	4	5
6	7.00	106.83	15.83	13.34	
8[a]	51.33	21.33	1.00	39.84	
10	14.50	2.50	96.50	20.00	
11[a]	10.25	56.75	4.75	17.25	57.00
12[a]	63.33	47.33	25.34	3.00	
13	18.41	2.75	20.42	87.92	
14[a]	49.33	34.83	2.84	42.00	
16	32.00	91.00	7.00	8.00	
19[a]	9.34	5.83	43.83	71.00	17.00
21	11.33	22.84	5.17	100.66	
22	13.16	4.99	5.83	36.02	91.00
1[b]	27.00	22.34	63.33	23.33	
3[b]	76.18	28.33	12.82	13.67	11.00

[a]Items which contain primary responses with very low frequencies, $f_o < 6$.

[b]Non-consensus items, but containing a single heavily-favored response.

Note.--N=155 Criterion: 50%=77.50 25%=38.75

Table 3

Consensus Items for Part 2

Items	Responses 1	2	3	4
1	36.00	1.50	2.00	97.00
2	2.00	28.00	84.00	18.00
4	10.09	28.58	10.75	93.58
5[a]	44.50	60.50	6.00	15.50
10	4.49	89.83	34.35	21.33
11	14.00	86.50	13.50	27.50
16	0	97.83	10.83	42.84
17[a]	75.09	52.58	9.08	5.25
19	97.82	4.18	23.99	8.18
7[b]	15.50	67.50	19.50	22.50
21[b]	13.83	29.15	67.34	28.68

[a]Items which contain primary responses with very low frequencies, $f_o < 6$.

[b]Non-consensus items, but containing a single heavily-favored response.

Note.--N=156 50%=78.00 25%=39.00

Table 4

Manova Results for Part 1 Scales vs. Vocation

Scales	Range	Scientists (N=149)		Philosophers (N=19)		Univariate F(1,66)	Significance	η
		Mean	S.D.	Mean	S.D.			
1	16-32	28.51	2.34	29.47	1.58	3.05	.05 < p < .1	.13
2	10-20	17.32	1.56	17.53	1.87	0.29	ns[a]	
3	2-4	3.12	0.89	3.68	0.75	6.94	p < .01[b]	.20
4	2-4	2.69	0.85	2.53	0.84	0.64	ns	
5	2-4	2.73	0.88	2.79	0.98	0.07	ns	
6	2-4	3.21	0.77	3.05	0.91	0.65	ns	
7	2-4	2.64	0.70	3.11	0.94	6.94	p < .01[b]	.20
8	2-4	2.21	0.52	2.00	0	2.99	.05 < p < .1	.13
9	2-4	2.95	0.73	3.05	0.85	0.34	ns	
10	2-4	2.28	0.60	3.00	1.00	20.49	p < .001[b]	.33
11	26-52	45.83	3.06	47.00	2.49	2.56	ns	

H_1: equality of dispersions, $\alpha = .01$ Manova $F(55,3242) = -0.015$ ns at .01 level

H_2: equality of centroids, $\alpha = .05$ Manova $F(10,157) = 3.51$ $p < .001$ $\eta = .43$

[a]ns = not significant at .05 level; [b]Decision: reject H_0

Table 5

Manova Results for Part 2 Scales vs. Vocation

Scales	Range	Scientists (N=148)		Philosophers (N=19)		Univariate	Significance	η
		Mean	S.D.	Mean	S.D.	F (1,165)		
1	5-10	8.13	1.42	8.58	1.71	1.62	ns[a]	
2	9-18	16.03	1.50	17.05	0.91	8.29	$p < .005$[b]	.22
3	10-20	16.58	2.33	17.47	2.48	2.44	$p < .20$	
4	24-48	40.74	3.56	43.11	3.42	7.40	$p < .01$[b]	

H_1: equality of dispersions, $\alpha = .01$ Manova $F(6,5554) = 2.29$ $.01 < p < .05$

H_2: equality of centroids, $\alpha = .05$ Manova $F(3,163) = 3.32$ $p < .05$ $\eta = .24$

[a]not significant at .05 level

[b]Decision: reject H_o

Table 6

Pairwise Contrasts of Minor Scales, Science Faculty and Philosophers of Science

Scientists (N=149)				
Scale Contrasts Scale X - Scale Y	$\bar{D}$	S.E.$_{\bar{D}}$	T(148)	p
3 - 4	0.43	.11	3.78	<.001
3 - 5	0.39	.12	3.23	.001
4 - 5	-0.04	.10	-0.40	.69
6 - 7	0.57	.10	5.68	<.001
6 - 8	1.00	.09	10.77	<.001
7 - 8	0.43	.08	5.34	<.001
9 - 10	0.67	.09	7.45	<.001

Philosophers (N=19)				
Scale Contrasts	$\bar{D}$	S.E.$_{\bar{D}}$	T(18)	p
3 - 4	1.16	.27	4.32	<.001
3 - 5	0.89	.30	3.03	<.01
4 - 5	-0.26	.25	-1.05	<.4
6 - 7	-0.05	.42	-0.13	>.8
6 - 8	1.05	.21	5.04	<.001
7 - 8	1.11	.22	5.14	<.001
9 - 10	0.50	.38	0.14	>.8

Scale 3: aim of science--theoretical
Scale 4: aim of science--classificatory
Scale 5: aim of science--social
Scale 6: scientific laws as empirical generalizations
Scale 7: scientific laws as confirmed theories
Scale 8: scientific laws as inviolable relations
Scale 9: scientific models as analogies
Scale 10: scientific models as roughly equivalent to theories

Table 7

t-Tests for Pairwise Contrasts within "Area of Science" Groups

Scale Contrasts	Biologists (N=59)		Geoscientists (N=13)		Chemists (N=44)		Physicists (N=33)	
	t(58)	p	t(12)	p	t(43)	p	t(32)	p
3 - 4	1.84	<.10	8.40	<.001	0.54	>.5	2.36	<.05
3 - 5	0.77	<.5	6.12	<.001	0.49	>.5	3.68	<.001
6 - 7	1.17	<.4	1.90	<.1	3.63	<.001	5.46	<.001
6 - 8	4.33	<.001	2.22	<.05	6.45	<.001	12.49	<.001
7 - 8	3.28	<.002	0.71	<.5	2.73	<.01	3.91	<.001
9 - 10	4.23	<.001	0.74	<.5	3.91	<.001	6.83	<.001
$\alpha = .01$	$_{.01}t(58) = 2.66$		$_{.01}t(12) = 3.05$		$_{.01}t(44) = 2.70$		$_{.01}t(33) = 2.74$	

TABLE 8

Frequency Count Results for Item 1 (Part 1)
Philosophers vs. Scientists

Alternative	Philosophers (N=23)		Scientists (N=155)	
	N	%	N	%
1	0	0	27.00	17.4
2	0.34	1.5	22.34	14.4
3	6.83	29.7	63.33	40.8
4	12.33	53.6	23.33	14.4
5	2.00	8.7	6.50	4.4
6	1.50	6.5	10.50	6.8
omits	0	0	2.00	1.3

$\chi^2(df=4) = 20.06$ $p < .001$

Note.--χ^2 test based on deleting "omits" and merging alt. (alternatives) 5,6

TABLE 9

Distribution of Opinion on Item 6 within Geographical Regions

Alt.	Northeast (N=58)		South (N=21)		Midwest (N=37)		West (N=41)	
	N	%	N	%	N	%	N	%
1	1	1.7	5	23.8	1	2.7	0	0
2	40	69.0	15	71.4	20	54.1	31	75.6
3	7	12.1	0	0	6	16.2	5	12.1
4	4	6.9	1	4.8	6	16.2	2	4.9
5	5	8.6	0	0	3	8.1	2	4.9
6	1	1.7	0	0	1	2.7	1	2.4

$\chi^2(df=9) = 27.40$ $p = .0012$

Note.--χ^2 based on deleting alt. 5,6

TABLE 10

Frequency Count Results for Item 7 (Part 1)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=155)	
	N	%	N	%
1	0	0	13.50	8.7
2	4.00	17.4	64.84	41.8
3	12.00	52.2	60.33	38.9
4	0	0	10.33	6.7
5	2.00	8.7	3.00	1.9
6	5.00	21.7	2.00	1.3
omits	0	0	1.00	0.6

$\chi^2(df=4) = 25.11$ $p < .001$

Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

TABLE 11

Distribution of Opinion on Item 7 within "Study in Nature of Science" Groups

Alt.	Large Amount (N=9)		Many (N=23)		Several (N=50)		Few (N=60)		Very few or None (N=17)	
	N	%	N	%	N	%	N	%	N	%
1	1	11.1	1	4.3	1	2.0	7	11.7	4	23.5
2	0	0	14	60.9	28	56.0	16	26.7	7	41.2
3	8	88.9	8	34.8	18	36.0	24	40.0	6	35.3
4	0	0	0	0	2	4.0	10	16.7	0	0
5	0	0	0	0	1	2.0	2	3.3	0	0
6	0	0	0	0	0	0	1	1.7	0	0

$\chi^2(df=9) = 25.60$ $p = .0024$

Note.--χ^2 test based on deleting alt. 5,6 and merging categories "large amount" and "many".

TABLE 12

Distribution of Opinion on Item 8 within "Area of Science" Groups

Alt.	Biologists (N=61)		Geoscientists (N=12)		Chemists (N=46)		Physicists (N=35)	
	N	%	N	%	N	%	N	%
1	10.00	16.4	2.00	16.7	23.33	50.7	15.50	44.3
2	7.00	11.5	3.00	25.0	7.33	15.9	3.50	10.0
3	0	0	0	0	0	0	1.00	2.9
4	27.00	44.3	3.00	25.0	5.34	11.6	4.50	12.9
5	6.00	9.8	2.00	16.7	4.00	8.7	2.00	5.7
6	1.00	1.6	0	0	1.00	2.2	1.50	4.3
omits	10.00	16.4	2.00	16.7	5.00	10.9	7.00	20.0

χ^2(df=15) = 32.45 p = .0058

Note.--χ^2 based on merging alt. 5,6

TABLE 13

Frequency Count Results for Item 9 (Part 1) Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=155)	
	N	%	N	%
1	2.83	12.3	59.83	38.6
2	3.34	14.5	31.84	20.6
3	6.50	28.3	18.00	11.6
4	2.33	10.1	28.33	18.3
5	2.00	8.7	9.00	5.8
6	6.00	26.1	5.00	3.2
omits	0	0	3.00	1.9

χ^2(df=4) = 20.98 p < .001

Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

TABLE 14

Frequency Count Results for Item 12 (Part 1)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=155)	
	N	%	N	%
1	4.00	17.4	63.33	40.9
2	16.00	69.6	47.33	30.5
3	0	0	25.34	16.3
4	0	0	3.00	1.9
5	0	0	6.00	3.9
6	3.00	13.0	4.0	2.6

$\chi^2(df=4) = 15.90$ $p = .004$

Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

TABLE 15

Frequency Count Results for Item 13 (Part 1)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=155)	
	N	%	N	%
1	8.00	34.8	18.41	11.9
2	0	0	2.74	1.8
3	0	0	20.42	13.2
4	6.00	26.1	87.92	56.7
5	3.50	15.2	11.50	7.4
6	3.50	15.2	7.00	4.5
omits	2.00	8.7	7.00	4.5

$\chi^2(df=4) = 19.47$ $p < .001$

Note.--χ^2 test based on the deletion of "omits" and alt. 6

TABLE 16

Distribution of Opinion on Item 14 within "Extent of Thought about Issues" Groups

Alt.	Many issues a lot (N=23) N	%	Some a lot, others a few times (N=30) N	%	Some a lot, others very little (N=43) N	%	Some a few times others very little (N=40) N	%	Most issues very little (N=19) N	%
1	12	52.2	6	20.0	11	25.6	13	32.7	5	26.3
2	4	17.4	4	13.3	5	11.6	13	32.5	8	42.1
3	1	4.3	1	3.3	3	7.0	0	0	0	0
4	4	17.4	13	43.3	17	39.5	6	15.0	3	15.8
5	1	4.3	4	13.3	4	9.3	3	7.5	2	10.5
6	1	4.3	0	0	2	4.7	3	7.5	0	0
omits	0	0	2	6.7	1	2.3	2	5.0	1	5.3

$\chi^2(df=12) = 27.39$ $p = .0068$

Note.--χ^2 test based on merging categories "some a few times, others very little" and "most issues very little", also merging "omits" and alt. 5,6

TABLE 17

Distribution of Opinion on Item 15 within Geographical Regions

Alt.	Northeast (N=58) N	%	South (N=21) N	%	Midwest (N=37) N	%	West (N=41) N	%
1	3	5.2	0	0	5	13.5	0	0
2	2	3.4	0	0	3	8.1	1	2.4
3	9	15.5	7	33.3	11	29.7	19	46.3
4	9	15.5	3	14.3	11	29.7	4	9.8
5	21	36.2	10	47.6	6	16.2	11	26.8
omits	14	24.1	1	4.8	1	2.7	6	14.6

$\chi^2(df=15) = 38.15$ $p < .001$

TABLE 18

Frequency Count Results for Item 20 (Part 1)
Philosophers vs. Scientists

	Philosophers (N=23)		Scientists (N=155)	
Alt.	N	%	N	%
1	1.00	4.3	24.50	15.7
2	11.34	49.4	36.84	23.8
3	1.50	6.5	55.50	35.8
4	4.83	21.0	18.33	11.8
5	1.00	4.3	8.00	5.2
6	3.33	14.5	7.83	5.0
omits	0	0	4.00	2.6

$\chi^2(df=4) = 13.89$ $p = .008$
Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

Table 19

Frequency Count Results for Item 21 (Part 1)
Philosophers vs. Scientists

	Philosophers (N=23)		Scientists (N=155)	
Alt.	N	%	N	%
1	0.50	2.2	11.33	7.3
2	3.84	16.7	22.84	14.7
3	0	0	5.17	3.3
4	11.83	51.4	100.66	64.9
5	4.00	17.4	6.50	4.2
6	2.83	12.3	1.50	1.0
omits	0	0	7.00	4.5

$\chi^2(df=4) = 16.06$ $p = .004$
Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

Table 20

Distribution of Opinions on Item 4 (Part 2)
within "Highest Academic Degree" Groups

Alt.	Ph.D. (N=128)		Masters (N=24)	
	N	%	N	%
1	9	7.0	1	4.2
2	22	17.2	8	33.3
3	4	3.1	4	16.7
4	85	66.4	8	33.3
5	3	2.3	1	4.2
6	4	3.1	1	4.2
omits	1	0.8	1	4.2

$\chi^2(df=3) = 14.15$ $p = .0027$
Note.--χ^2 test based on deletion of alt. 5,6, "omits"

Table 21

Frequency Count Results for Item 12 (Part 2)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=156)	
	N	%	N	%
1	2.00	8.7	53.75	34.4
2	1.50	6.5	22.25	14.3
3	4.50	19.6	14.25	9.1
4	1.00	4.4	30.75	19.7
5	10.00	43.5	27.00	17.3
6	1.00	4.4	3.00	1.9
omits	3.00	13.0	5.00	3.2

$\chi^2(df=4) = 18.04$ $p = .001$
Note.--χ^2 test based on deletion of "omits" and alt. 6

Table 22

Frequency Count Results for Item 15 (Part 2)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=156)	
	N	%	N	%
1	0.50	2.2	15.33	9.8
2	0	0	38.17	24.4
3	0.33	1.4	41.16	26.4
4	15.83	68.9	49.01	31.4
5	5.00	21.7	4.34	2.8
6	1.34	5.8	3.99	2.6
omits	0	0	4.00	2.6

$\chi^2(df=4) = 32.98$ $p < .001$

Note.--χ^2 test based on deleting "omits" and merging alt. 5,6

Table 23

Frequency Count Results for Item 16 (Part 2)
Philosophers vs. Scientists

Alt.	Philosophers (N=23)		Scientists (N=156)	
	N	%	N	%
2	5.50	23.9	97.83	62.6
3	1.00	4.4	10.83	7.0
4	6.00	26.1	42.84	27.4
5	7.50	32.6	2.00	1.3
6	3.00	13.0	2.50	1.6

$\chi^2(df=3) = 49.20$ $p < .001$

Note.--χ^2 test based on merging of alt. 5,6

Table 24

Distribution of Opinion within "Extent of Thought about Issues" Categories on Item 22 (Part 2)

Alt.	Many issues a lot; some a lot, others a few times (N=58)		Some a lot, others very little (N=41)		Some a few times, others very little; most very little (N=31)	
	N	%	N	%	N	%
1	26	44.8	18	43.9	9	29.0
2	1	1.7	0	0	6	19.4
3	27	46.6	16	39.0	12	38.7
4	4	6.9	7	17.1	4	12.9

$\chi^2(df=6) = 18.94$ $p = .004$

Synopsis of the Findings

Academic scientists and a group of selected philosophers of science generally hold the perspective that all scientific description involves some measure of interpretation and judgment, that scientific facts inextricably mix observation and interpretation, that a scientist usually has a definite idea of the kinds of observations he expects to make, and that the scientist reflects an active relation between observer and world in presenting theoretical ideas. In contrast, they generally reject the perspective that scientific description is the transmission of uninterpreted information, that scientific facts are theory-free pieces of raw, uninterpreted information, that scientific laws are demonstrated relations which are absolutely certain, that scientific models are intended to photographically represent reality and that the scientist copies nature and presents her as given in itself. There is evidence that with increasing knowledge and study in the nature of science, scientists are more confirmed in the above perspective.

Science faculty and the selected philosopher group also embrace the perspective that theories function as technical, specialized 'Weltanschauungen', that successive theories in a field often change the meaning of familiar terms and add new postulates, that commitment to new theories often involves interest in a new problem-field and a transformation of vision, that well-established theories function as dogmas in the sense of being taught as the core of established knowledge and of being the basis for judging the pertinence and scope of research problems. In connection with this perspective, southern scientists are more hesitant to affirm that new theories are often incommensurable with their predecessors than scientists in other parts of the country.

As a result of the two major perspectives described above, a composite perspective, called "science as the process and product of a dynamic man-world interaction", is also affirmed by natural scientists and the philosopher group. A contrasting perspective, science as a literalistic description of nature in which the scientist faithfully replicates nature as given in itself, is rejected by both groups. Moreover, with increasing exposure to and study of the literature on the nature of science, espousal of this viewpoint, albeit small, increases.

Other findings in the study indicate that both groups generally believe that fields of science evolve through periods of revolution and normalcy. They also believe that objectivity in science is community dependent, i.e., it presumes a scientific community sharing a common set of assumptions and concepts, that the selection of experiments largely depends on what problems the scientific community is concerned about at the moment, that objectivity consists of intersubjective testability and rests upon the scientist's willingness to accept experimental proof. In contrast, both groups generally eschew the position that scientific objectivity is community independent, i.e., that objective judgments and decisions are impersonal, detached, disinterested and free of subjective intrusions, that the scientists is indifferent about the outcome of his research and removes all bias from judgments made in his work. A small negative correlation between this viewpoint and chronological age exists.

Other results show that both groups feel that scientific theories are not conclusively verified or falsified, that a theory can be enforced or weakened by new data but not proven or falsified, that a theory is discarded when contradictory evidence is strong enough to erode confidence in it and a viable alternative exists. In contrast, they express little support for the perspective that much experimentation and observation prove the correctness of a theory although it may take a long time. Physicists are more unanimous in their opinion than other scientists that it is mean-

ingless to speak of 'proving' a theory; they also appear to have given more thought to this issue and its difficulties.

A composite perspective of the three viewpoints just described is also affirmed by academic scientists and the selected philosopher group. This perspective asserts that science is characterized by the interaction of its cognitive (theoretical-confirmational) structure with its communal self-consciousness and social dynamic, rather than by the externality and independence of its cognitive structure. The philosophers were more confirmed in their affirmation of this perspective than the scientists.

On the issue of what is the chief aim of science, one is clearly dominant for both group, viz., the chief aim is the search for pattern and coherence in nature via theoretical structures. The philosopher group gives greater support to this claim than the science faculty. Geoscientists favor this aim more than other science groups. The classificatory aim and social benefit aim receive most support among biologists and chemists. No group clearly ranks one above the other in preference. Scientists who have given increasing thought to the IVNS issues are increasingly convinced that the chief aim is theoretical.

On the issue of the nature of scientific laws, one view is generally dominant among academic scientists, viz., laws are empirical generalizations supported by a vast body of consistent experience. Among the philosophers, however, no preference as a group is exhibited between this view and the view that a law is a theory supported by much experimentation and observation. The view that scientific laws are dictated by nature and cannot be violated is widely rejected. Biologists are not predisposed toward the first view over the second as other science groups are. Neither are college faculty, masters-degree faculty, younger-aged faculty, or midwestern faculty. Scientists with increasing knowledge and study in the nature of science exhibit decreasing support for the third view--that laws are inviolabe relations.

[continue on next page]

On the nature of scientific models, science faculty and philosophers totally reject the notion that models are intended to photographically represent reality. A plurality of scientists feel that a theoretical model is a simplification of a theory, providing a means of visualization. However, while the scientists make a distinction between models as analogies which exhibit an identity of structure to some physical system and models as roughly equivalent to theories, preferring the former view, the philosophers express no clear preference one way or the other. Among the science faculty, geoscientists and midwestern faculty do not clearly lean towards the first view as other science groups do.

The results of the investigation point to other relationships. Many biologists deny that scientists represent the objects and events of laws in an 'ideal world', while a substantial proportion of chemists and physicists affirm that the idealization is the result of the benefit obtained from formulating simplified conditions.

The respondents generally agree that theoretical models indicate similarities to more easily grasped concepts, suggest new areas of experimentation, give clues concerning new laws, but should not be viewed as temporary psychological aids in the formation of theories, which ideally contain only a logical formalism.

A plurality of the scientists believe that 'atoms', and presumably some other theoretical entities, exist in the sense that the concept operates successfully in science. They also affirm that theories are essentially useful calculating devices; practical tools and useful techniques for organizing research. The philosophers, on the other hand, assert that 'objects' approximately corresponding to the concept 'atoms' exist, and that the 'instrumentalist' view of theories is incomplete and inadequate.

Both groups agree that the view of theories as no more than summaries of data or mental devices for classifying observations is incomplete because, for one thing, it does not take into account the predictive power of theories.

Ph.D. science faculty and the philosopher group hold the view that the greatest threat to a scientific proposition is the future discovery of contradictory facts, but more than half of the masters-degree faculty choose other reasons, such as the failure to find broad application or to be proved conclusively.

Some disagreement between scientists and philosophers exists on the factors which influence a scientist in his choice of research. While most scientists feel that the cultural milieu, the cost and accessibility of experimental apparatus, and prior expectations are influencing factors, over a third of the scientists are of the opinion that less influential is the desire to find a crucial experiment that will upset a current theory. The philosophers feel that all of these factors were quite influential.

On the issue of the process by which theoretical entities arise, the science faculty is nearly equally divided among the views that theoretical entities are mental constructs which may be suggested by data but are never given directly by nature, that a theory is produced by induction from a large quantity of facts and that theoretical entities arise from comparison of recurrent uniformities. In contrast, the philosopher group exhibits strong consensus for the first proposition alone.

On the matter of 'the scientific method', the consensus among scientists is that it is basically a systematic approach to understanding natural phenomena, while the philosophers are divided between this view, the view that it is a general attitude to work rationally and honestly, and other more complex and detailed notions.

From the responses of the science faculty to judgments about science textbooks, it is evident that a plurality believe textbooks are designed to bring about commitment to a set of ideas and finished achievements. The philosophers are even more unanimous in this judgment.

In comparing science and theology, the science faculty largely dichotomize their response between the notion that science and theology are similar insofar as their respective communities play an essential role in guiding systematic inquiry and the notion that they are different in that science has few presuppositions about reality but theology has many. A plurality of the philosophers prefer the first view.

Concerning science and ethics, the college scientists, for the most part, dichotomize their response between the view that scientific knowledge is ethically neutral and the view that scientists have a moral responsibility to society because the application of science has transfigured the world. Many selected both responses.

The findings of the study identify and describe the views, perspectives and opinions of academic scientists in a primitive, unsophisticated form. The results indicate that few statistically significant relationships between viewpoints and demographic variables exist. It is significant that these variables have little impact on the perspectives and views of the nature of science, i.e., that extent of study in and thought about the nature of science makes little difference for scientists, that academic degree or chronological age makes little difference for scientists. One would think that a priori these variables should be related to the views and perspectives, and that area of science and type of educational institution very likely are related. The one variable which one might suspect is unlikely to be related, viz., geographical region, has evidenced more relationship than most of the rest. The results imply that understandings and views on the nature of science is an extensive, complex domain to which one's vocation as academic scientist or philosopher of science is related at many points, but to which the other selected demographic characteristics relate at few points. Where those relationships occur is presently not predictable, and so this study can be used to locate them.

Significance and Implications of the Study

What was hoped to be learned from this study before it was initiated? The answer is that it was hoped some information could be assembled on how academic scientists view the nature of science, how they feel about science, what they believe about science, how their views compare with some prominent philosophers of science, and whether these views are related to some selected demographic characteristics.

If the nature of science is a vastly complex, abstruse domain for which present language and concepts seem inadequate, is such a study possible? Is any empirical study possible? Granted that present insights of scholars are fairly shallow, that any real understanding may await a science of language and consciousness, surely the shallowness is judged by those who have devoted so much effort to the task that they have some perception of how far they have yet to go. And surely such scholars would not claim to know no more than the man on the street. At least these scholars have some notion of the misconceptions concerning the nature of science that circulate among the public. They may not

know the extent of the naivete about the nature of science that exists among primary, secondary, college students and teachers, and most of the general public, but they would certainly recognize it when it was encountered. Thus, much can be taught about the nature of science to this audience that is more accurate and more faithfully descriptive than what they now believe and misperceive. Level of understanding is obviously a relative matter. Most public school graduates and college graduates will never grapple with problems on the nature of science at the level that scholars operate. Yet, discourse on the nature of science at the secondary school level is possible and highly desirable. It is desirable for the same reason scholars feel their own efforts have worth, namely because understanding is promoted.

The results of the study can aid teachers in describing what scientists' and some philosophers' views are concerning numerous aspects of the nature of science, in identifying many understandings on which the two groups are agreed and those on which they disagree, in specifying differences between areas of science or those with different degrees of knowledge about the nature of science. Obviously, the results may need translation to a level of understanding commensurate to the school audience which the teacher is addressing.

Another use for the results of the study is as an empirical basis for evaluation of instruments currently used or yet to be constructed to assess understanding of the nature of science among students.

Several additional questions need to be faced at this point. First, why waste the time and effort on the study? Don't we already know everything that the study has assessed? The answer is clearly no. We have had little more than conjectures to operate on concerning what scientists' views are, i.e., as a professional group in this country, how they feel and what they believe about the nature of science, whether many or few differences with philosophers exist, at what points differences exist, whether chronological age or academic degree or extent of study in the nature of science, etc., makes a difference, and if so, where do those differences occur. Certainly, a few scientists have written books on how they view the nature of science and sometimes they assert that they are speaking for all scientists, but they have not made a systematic, extensive check of their views with hundreds of other scientists from all parts of the country in all areas of science.

Given that the participants respond honestly, won't their answers be inarticulate, inconsistent and simple-minded since most scientists have probably thought little about the nature of science? Because the participants need only select from given statements or express agreement/disagreement with given statements, they are not required to verbalize their responses but may do so as a free response if they wish. One can also check the responses of those who have had little exposure to the literature on the nature of science with those who have had much. The results of the study show that seldom does this variable play a role. This study is a study of the explicit beliefs and opinions of scientists. It must be granted that the implicit beliefs might be different because of subtle factors not immediately apparent.

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Appendix A

Questionnaire on Demographic Information

1. What is your age?

___(1) Below 33
___(2) 33-37
___(3) 38-43
___(4) 44-50
___(5) 51 or more

2. How much study and reading in the philosophy, history, or sociology of science have you done?

___(1) A large amount including lectures, books, articles, etc.
___(2) Many " " " "
___(3) Several " " " "
___(4) A few " " " "
___(5) Very few or none

3. How much have you studied or thought about the issues in the Survey on the Nature of Science?

___(1) Many issues quite a lot
___(2) Some issues quite a lot, others a few times
___(3) Some issues quite a lot, others very little
___(4) Some issues a few times, others very little
___(5) Most of the issues very little or not at all

4. Type of educational institution in which you have been employed the most.

___(1) University
___(2) Four-year college
___(3) Two-year college or junior college

5. Geographical region of the U.S. in which you have predominantly lived.

___(1) Northeast
___(2) South
___(3) Midwest
___(4) West

6. Highest academic degree attained

___(1) Ph.D. or equivalent
___(2) Masters or equivalent
___(3) Bachelors
___(4) Other (please specify) _____

Appendix B

INVENTORY OF VIEWS ON THE NATURE OF SCIENCE(PART 1)

Directions: Please select the one best response in your opinion for each item and mark your choice. You may mark two or more responses if they seem equally good. If you do not like any of the responses, then please add your own response. If you have no opinion or do not understand an item, simply leave it unanswered and go on. The term 'science' or 'scientists' is used throughout to refer to 'natural science' or 'natural scientists'. 'Natural science' refers to the physical sciences (chemistry and physics), the biological sciences, and the earth sciences.

Theme I: Facts and Observations

1. In your view which is the best general statement concerning scientific facts?

___(1) Scientific facts are pieces of raw, uninterpreted information which are universally understood in the same manner.
___(2) Scientific facts are theory-free observations.
___(3) Scientific facts inextricably mix observation and interpretation.
___(4) Scientific facts are interpretations of our experience depending upon our conceptual baggage and particular interests.
___(5) None of the above.
___(6) _____

2. Scientific observations
___(1) which are unpredicted have played a role in the majority of scientific achievements.
___(2) are interpretation-free in the sense that if two scientists individually examine the same phenomenon, they will make identical reports.
___(3) are planned and expected in that a scientist usually has a definite idea of the kinds of observations he or she expects to make during an experiment.
___(4) are weighted in value depending upon the reputation of the researcher.
___(5) None of the above.
___(6) _____

3. Which, if any, of the following general statements (1-4) about the observational reports of a molecular biologist using an electron microscope do you think is UNSATISFACTORY?
___(1) The observational reports are exact, uninterpreted reports about an external world.
___(2) The observational reports are descriptions of what he judges that he perceives and considers worth reporting.
___(3) The observational reports reflect an active relation between observer and world, not a passive state of reception.
___(4) The observational reports implicitly bespeak of a man-world consisting of observers and the observed.
___(5) All of the above statements are satisfactory.

Theme II: Aim of Science

4. For myself the principal aim of science is to
___(1) provide intellectual and aesthetic satisfaction.
___(2) search for unity, pattern, and coherence.
___(3) discover, collect, and classify facts about nature.
___(4) provide the people of the world with the means for leading better lives.
___(5) None of the above.
___(6) _____

5. In my mind the primary purpose of science is
___(1) the furtherance of the well-being of humanity.
___(2) the compilation and categorization of all laws and facts about natural phenomena.
___(3) the mastery and control of nature through a set of relations that successfully predict events.
___(4) the establishment of theoretical structures which integrate and explain.
___(5) None of the above.
___(6) _____

Theme III: Scientific Laws

6. Which of the following is the best description in your judgment of a scientific law?
___(1) It is an exact report of a set of observations.
___(2) It is a generalized statement of relationships among natural phenomena.
___(3) It is a theoretical explanation of a natural phenomenon.
___(4) It is dictated by nature and cannot be violated.
___(5) None of the above.
___(6) _____

7. In my mind a law in the natural sciences is
___(1) a demonstrated relation which is absolutely certain.
___(2) an inference from a vast body of consistent experience.
___(3) a theory supported by much experimentation and observation.
___(4) a theory proven true.
___(5) None of the above.
___(6) _____

8. The representation of the objects and events of many scientific laws in a non-existent 'ideal world'
___(1) is the result of the benefit obtained from formulating simplified conditions which are readily conceptualized.
___(2) is compensated for by adjusting the laws to 'reality'.
___(3) results in the importance of aesthetic considerations in science.
___(4) The premise is false; science does <u>not</u> represent objects and events in an 'ideal world'.
___(5) None of the above.
___(6) _____

Theme IV: Scientific Models

9. Which of the following is the best statement in your opinion about the relation between a scientific model and the theory with which it is associated?
   ___(1) A model is a simplification of a theory, providing a means of visualizing a theory.
   ___(2) A scientist begins research by imagining a simple description of a system, i.e. a model, then he constructs the theory around and upon the model.
   ___(3) Generally speaking, a model and a theory are roughly the same thing.
   ___(4) A theory is the aggregate of a model, or series of overlapping models, and a logical system (e.g. a mathematics).
   ___(5) None of the above.
   ___(6) _____

10. In my view scientific models generally are
   ___(1) physical replicas of natural phenomena.
   ___(2) intended to photographically represent reality.
   ___(3) analogies which exhibit an identity of structure to some physical system.
   ___(4) roughly equivalent to theories.
   ___(5) None of the above.
   ___(6) _____

11. Which of the following statements (1-4) about models associated with a theory do you think is LEAST defensible?
   ___(1) Such models promote understanding by indicating similarities to more familar and easily grasped concepts.
   ___(2) Such models are temporary psychological aids in the formation of theories, which ideally contain only a logical system (e.g. a mathematics).
   ___(3) Such models often suggest new areas of experimentation or ways in which a theory can be extended.
   ___(4) Such models may give clues concerning the formulation of new laws.
   ___(5) All of the above statements are equally defensible.

Theme V: Theoretical Terms

12. What for you is the strongest sense in which 'atoms' exist?
   ___(1) The concept operates successfully.
   ___(2) 'Objects' at least approximately corresponding to the concept exist.
   ___(3) The concept has a clear-cut experiential denotation.
   ___(4) The concept is directly connected to sensory perception.
   ___(5) None of the above.
   ___(6) _____

13. The concept 'demons' is not part of the repertoire of science because it
   ___(1) lacks explanatory power.
   ___(2) involves appeal to unfamiliar qualities.
   ___(3) is non-observable.
   ___(4) fails to be testable.
   ___(5) None of the above.
   ___(6) _____

Theme VI: Scientific Theories

14. From my knowledge and experience, when a new theory replaces an older theory, it is frequently incompatible with its predecessor in the sense that
___(1) successive theories often change the meaning of familiar terms and/or add new postulates.
___(2) the old theory is erroneous and the new theory is a correction of former mistakes.
___(3) a new battery of experimental apparatus must be designed.
___(4) The premise is false; new theories are not usually incompatible with their predecessors.
___(5) None of the above.
___(6) _____

15. When a new theory replaces an older theory, it is often incommensurable (uncomparable) with its predecessor in a number of aspects. Do you DISAGREE with any of the following aspects (1-3)?
___(1) A new theory will direct scientific attention to a new problem-field and a new subject of study.
___(2) Adopting a new theory is often like undergoing a transformation of vision or a gestalt-switch because scientists look in the same places and see new and different things.
___(3) The formulation of a new theory requires an unprecedented creativity.
___(4) All of the above are aspects of incommensurability.
___(5) The premise is false; new theories are not incommensurable with their predecessors.

16. In presenting or representing the underlying structures of natural phenomena I, as a scientist,
___(1) inject many personal elements which reflect my personal creativity.
___(2) reflect an active relation between observer and world rather than a passive state of reception.
___(3) am like a photographer presenting photographic images of nature.
___(4) set out to copy nature and present her a factually given.
___(5) None of the above.
___(6) _____

17. Theories and the networks of scientific research which have sprung from them may guide a scientific group's future research in a number of ways. Do you DISAGREE with any of the following ways (1-4)?
___(1) By defining what kinds of questions may legitimately be asked.
___(2) By indicating what mathematical or experimental techniques are likely to be fruitful.
___(3) By delineating precisely or exactly the limits of their own extension.
___(4) By specifying what types of solutions are admissible.
___(5) All of the above are ways in which a theory may guide future research.

18. If two incompatible theories have divided a segment of the scientific community, which property of theories do you think would most contribute to resolving the schism?
___(1) Future promise as a research guide.
___(2) Parsimony of theoretical premises or initial assumptions.
___(3) Anticipated benefit for society.
___(4) Ability to solve old research puzzles.
___(5) Aesthetic appeal, e.g. elegance.
___(6) _____

19. Well-established theories function as dogmas within particular scientific traditions in several respects. The following are some examples. Do you DISAGREE with any of the following statements (1-3)?

___(1) They (the established theories) are taught to prospective scientists as the core of established knowledge which must be mastered in "learning the trade".

___(2) They become the basis for judging the pertinence and scope of research problems.

___(3) They function as higher authorities in the attempted suppression of anomalous phenomena.

___(4) All of the above statements are true.

___(5) The premise is false; well-established theories do not function as dogmas in any fashion.

20. One view of scientific theories holds that theories are no more than useful calculating devices for making accurate predictions, techniques for suggesting and deriving new experiments, practical tools for organizing research and achieving technical control. Such a view of theories in my opinion

___(1) is basically correct because there are no more important properties of a theory.

___(2) is incomplete because theories are judged not only by their usefulness, but also by their truth or falsity.

___(3) is basically correct since, for one thing, theories are frequently discarded for more useful or practical ones.

___(4) is inadequate because it relegates the reality of theoretical entities such as 'atoms' and 'electrons' to unimportance.

___(5) None of the above.

___(6) _____

21. One view of scientific theories is that theories are no more than summaries of data, resumés of experience, labor-saving mental devices for classifying observations, convenient schemes for categorizing facts. This view of theories in my judgment

___(1) is essentially correct because theoretical statements about atoms, electrons or molecular chains, for example, are not meaningful unless they are equivalent to a set of statements about experimental results and operations.

___(2) is inadequate because some theories, e.g. General relativity, hold the allegiance of the scientific community by their intellectual beauty and comprehensiveness as much as by supporting evidence.

___(3) is essentially correct because the main purpose of a theory is to economize thought.

___(4) is incomplete because an important property of theories is their predictive power.

___(5) None of the above.

___(6) _____

22. Which of the following terms (1-4), if any, do you think are NOT appropriate criteria for evaluating theories?

___(1) Fruitfulness or fecundity in suggesting new laws.

___(2) Extensibility--comprehensiveness in showing underlying unity in diverse phenomena.

___(3) Consistency of internal relations.

___(4) Simplicity

___(5) All of the above are appropriate in judging theories.

INVENTORY OF VIEWS ON THE NATURE OF SCIENCE (PART 2)

Directions: Please select the one best response in your opinion for each item and mark your choice. You may mark two or more responses if they seem equally good. If you do not like any of the responses, then please add your own response. If you have no opinion or do not understand an item, simply leave it unanswered and go on. The term 'science' or 'scientists' is used throughout to refer to 'natural science' or 'natural scientists'. 'Natural science' refers to the physical sciences (chemistry and physics), the biological sciences, and the earth sciences.

Theme I: Objectivity

1. In considering the objectivity of scientific knowledge, one prudently should recognize that
   ___(1) the validity of scientific knowledge is independent of the scientific community.
   ___(2) the evaluation of new knowledge is not influenced in any way by the interests and concerns of scientists.
   ___(3) the present body of scientific knowledge is free of subjective intrusions by researchers.
   ___(4) the selection of experiments largely depends on what problems the scientific community is concerned about at the moment.
   ___(5) None of the above.
   ___(6) _____

2. Of the following, which is the best statement about the objectivity of the scientist in your judgment?
   ___(1) The scientist is basically objective because he is indifferent about the conclusions and outcome of his work.
   ___(2) The scientist is objective because making progress and achieving answers is a matter of grinding things out via the scientific method.
   ___(3) The scientist's objectivity consists of intersubjective testability, i.e. agreement between members of the scientific community on matters of observation and verification.
   ___(4) The scientist's objectivity is the result of the fact that science is impersonal throughout.
   ___(5) None of the above.
   ___(6) _____

3. Of the following statements, which comes closest to your view of objectivity in science?
   ___(1) Objectivity is a distinctive virtue of persons who become scientists because of their ability to remove bias from judgments made during their work.
   ___(2) The objectivity of the scientist depends upon the 'hardness' of the facts, i.e. the degree to which the facts are a part of everyone's experience.
   ___(3) The scientist's objectivity is a result of conditioning and training in the minimizing of personal interpretation.
   ___(4) Objectivity rests upon the scientist's willingness to accept experimental proof.
   ___(5) None of the above.

Theme II: Verification and Falsification

4. Generally speaking, in my opinion the greatest threat to a scientific proposition in remaining a permanent part of the body of science lies in
   ___(1) changes in the methods and instruments of science.
   ___(2) its (the proposition's) failure to find successful application in more than a limited range of phenomena.
   ___(3) its failure to be proved conclusively.
   ___(4) the discovery of contradictory facts.
   ___(5) None of the above.
   ___(6) _____

5. Concerning the verification of a scientific theory, I think that
   ___(1) experimentation and observation proves the correctness of a theory.
   ___(2) a theory can be enforced or weakened by new data, but not proven or falsified.
   ___(3) theories are sometimes conclusively verified without recourse to experimentation or observation.
   ___(4) a theory is usually discarded as soon as a piece of experimental evidence is found which falsifies it.
   ___(5) None of the above.
   ___(6) _____

6. Scientific theories are not proven conclusively true or false because
   ___(1) there is never one theory that is in complete agreement with all known data.
   ___(2) nature is statistical and scientists can only make probability statements.
   ___(3) The premise is false; scientific theories <u>can</u> be proven conclusively true or false.
   ___(4) It is meaningless to speak of 'proving' a scientific theory.
   ___(5) None of the above.
   ___(6) _____

7. On the matter of the 'verification of a scientific theory', I have decided that
   ___(1) it always takes a long time to prove that a theory is true.
   ___(2) a theory is discarded when a piece of contradictory evidence is strong enough to erode confidence in the theory as a research guide.
   ___(3) some theories are still doubted after they are proven true.
   ___(4) it is meaningless to talk about 'verifying a theory'.
   ___(5) None of the above.
   ___(6) _____

8. In the eighteenth century when the phlogiston theory was the dominant theory of chemistry it was known that metallic oxides (calx) weighed more than the metal, a fact which is contradictory to the theory to some extent. This one fact, however, did not upset the theory. Such incidents also happen today in my view because
   ___(1) there may not be an alternative theory to account for the variant observations.
   ___(2) scientists are slow to change their ideas once a scheme has been established.
   ___(3) scientists make mistakes.
   ___(4) theories are <u>easily</u> modified to take into account even apparently contradictory facts.
   ___(5) None of the above.
   ___(6) _____

Theme III: Progress in Science

9. In any given field or specialty of natural science, there are times (revolutionary science) when major disagreements over theory, methods, and types of legitimate questions and solutions occur. There are also times of normalcy when relative unanimity in these matters exist. Which of the following, if any do you think also characterizes the latter?
   ___(1) The search for unanticipated and unexpected phenomena.
   ___(2) The absence of interesting and challenging problems, or the failure to recognize them.
   ___(3) Efforts to force nature into conceptual boxes.
   ___(4) The premise is false; such a characterization of science fails in one or more respects.
   ___(5) None of the above.
   ___(6) _____

10. Use of the term 'revolution' to describe the transition from one particular tradition of scientific research to another, e.g. from Newtonian mechanics to Einsteinian mechanics, is primarily a reflection of the
   ___(1) speed of the change to the new tradition.
   ___(2) impact on the scientific community which required a complete restructuring of the way through which a portion of the world was viewed.
   ___(3) new vistas of research which are added to the old.
   ___(4) The term 'revolution' is never an appropriate one to use in describing progress in science.
   ___(5) None of the above.
   ___(6) _____

Theme IV: Science and Society

11. Certain human values ostensively appear wherever scientific activity has flourished, e.g. independence of observation and thought, dissent from established ideas, freedom for original thinking. In my opinion these values are derived from
   ___(1) the collective virtue of individual scientists.
   ___(2) the conditions necessary for the practice of science.
   ___(3) the peculiar tradition of western civilization.
   ___(4) The premise is false in one or more respects.
   ___(5) None of the above.
   ___(6) _____

12. When a scientist selects a certain subject for investigation or when his interest is engaged in a certain direction, a number of factors determine his choice. Generally speaking, which one of the following factors (1-4) do you think is <u>LEAST</u> influential in this respect?
   ___(1) The aspiration to find a crucial idea or experiment that will upset an entire theory currently held.
   ___(2) The cultural milieu, the spirit of the age in which one lives, or the frame of mind of the epoch in which a scientist finds himself.
   ___(3) The cost and accessibility of experimental apparatus or computer usage.
   ___(4) Certain other areas are uninteresting because the scientist thinks he already knows the outcome.
   ___(5) All of the above factors are quite influential.
   ___(6) _____

Theme V: Presuppositions of Scientists

13. Which of the following presuppositions (1-4) do you NOT hold as a scientist?
___(1) Nature exhibits orderliness and regularity.
___(2) No physical event occurs without a prior physical cause.
___(3) Nature is mathematical, i.e. nature strictly adheres to one or more mathematical systems.
___(4) Natural laws are not restricted in historical time or space, i.e. the laws discoverable here and now are no different elsewhere and some other time.
___(5) I hold all of the above presuppositions.

14. Which of the following assumptions do you make as a scientist?
___(1) All natural phenomena have natural causes.
___(2) Repetition of an experiment might not produce the same results.
___(3) Some natural phenomena are too complex to ever be explained by science.
___(4) Physical objects and phenomena are so indissolubly connected with the rest of the world that we can never adequately analyze them.
___(5) None of the above.

Theme VI: Processes of Sciencing

15. How do you think theoretical entities, e.g. gene, electron, usually arise?
___(1) They arise from simple enumeration and comparison of recurrent uniformities.
___(2) They are generalizations directly inferred from particular experimental sequences.
___(3) Using induction one produces a theory after having amassed and catalogued a large quantity of facts.
___(4) They are mental constructs which may be suggested by data but are never given directly by nature.
___(5) None of the above.
___(6) _____

16. In your judgment which of the following is the best statement about the 'scientific method'?
___(1) There is one general method consisting of X steps which leads to discoveries.
___(2) The scientific method, while varying in detail, is a systematic approach to understanding natural phenomena.
___(3) No two pieces of scientific research utilize the same method.
___(4) The scientific method is a general attitude among scientists to work rationally and honestly.
___(5) None of the above.
___(6) _____

17. From my knowledge and experience, the dominant process in bringing about new scientific laws is
___(1) discovery by carrying out experiments and examining the data.
___(2) invention of a new hypothesis and then testing to see if it is true.
___(3) prediction from theories invented to explain old laws.
___(4) the extrapolation of old laws.
___(5) None of the above.
___(6) _____

Theme VII: Characteristics of the Scientific Community

18. In my opinion, introductory textbooks in science, generally speaking,
___(1) attempt to present past scientific achievements in their original historical context.
___(2) present an image of science that includes competition between different views of nature, disagreement, struggle, transformation.
___(3) are designed to bring about commitment to the set of finished scientific achievements.
___(4) cannot be generally characterized.
___(5) None of the above.
___(6) _____

19. Which of the following, if any, do you think is a basic attribute of scientists as a group?
___(1) The motivation for studying the physical universe is mainly curiosity—the desire to know.
___(2) The general scientific community is relied upon by scientists to guide them in making conclusions from experiments.
___(3) Scientists are more systematic thinkers than other professional groups.
___(4) The motivation for studying the physical universe is mainly the technological betterment of society.
___(5) None of the above.
___(6) _____

Theme VIII: Science vs. Other Disciplines

20. The fields of natural science and theology in my judgment
___(1) are different in that scientific judgments contain no personal involvement or influence, but theology is a collection of personal judgments.
___(2) are similar in that their respective academic communities are essential in the function of guiding systematic inquiry, including the defining of acceptable questions, techniques, and solutions.
___(3) are different in that science has few, if any, presuppositions about the world or reality, but theology is founded on a number of presuppositions about the world and reality.
___(4) are similar in that both extract single factors from the total situation of life and study them by ignoring or randomising other factors.
___(5) None of the above.
___(6) _____

21. The fields of natural science and social science in my view
___(1) are similar in that the chief goal of both is the discovery of universal laws.
___(2) are different in that the judgments of natural science are objective because the investigator does not interfere with the object, but observation and interpretation in social science are influenced by the values and actions of the investigator.
___(3) are similar in that both seek to establish connections between particular events and make use of generalizations in understanding events.
___(4) are different in that the phenomena of natural science are recurrent, reproducible, and regular, but the phenomena of social science are nonrecurrent, unique, and erratic.
___(5) None of the above.
___(6) _____

22. With regard to the ethical status of science, which of the following statements do you think is most accurate?
___(1) Scientific knowledge is ethically neutral.
___(2) The scientist assumes no moral responsibility if his research findings are used destructively against society.
___(3) Because the application of science has transfigured the world, scientists have a moral responsibility to society.
___(4) Scientific knowledge is open to moral judgment if the means of obtaining it are open to moral judgment.
___(5) None of the above.
___(6) _____

Appendix C

Scales of IVNS and Their α Coefficients

Part 1

Scale 1: Scientific description and human judgment
α(scientists)=.68 α(philosophers)=.48

1A: All scientific description involves human judgment.
α(scientists)=.53 α(philosophers)=.53
Item-alternatives: 1-3, 2-3, 3-1, 12-1, 16-2
Description: There are no uninterpreted facts; scientific facts inextricably mix observation and interpretation. We organize our experience in the light of particular interests; we attend to selected features; the scientist usually has an idea of the kinds of observations he expects to make during an experiment. Theorizing reflects on active relation between observer and world. Theoretical entities, e.g. 'atoms', are not factually given, but exist by virtue of the successful operation of their concepts in science.

1B: Scientific description requires no judgment.
α(scientists)=.71 α(philosophers)=.47
Item-alternatives: 1-1, 1-2, 2-2, 3-4, 6-1, 6-4, 7-1, 10-1, 10-2, 16-3, 16-4
Description: Facts are given absolutely and require no judgment; they are pieces of raw, uninterpreted information; they are theory-free, interpretation-free observations. Scientific observational reports do not reflect or implicitly bespeak of a man-world interaction. Statements of scientific law are exact reports of inviolable relations dictated by nature. The scientist is like a photographer making photographic images; his models are replicas of natural phenomena; his theories are copies of nature as she is factually given.

Scale 2: Functions of Scientific Theories
α(scientists)=.70 α(philosophers)=.68

2A: Theories function as technical, specialized 'Weltanschauungen',
α(scientists)=.53 α(philosophers)=.66
Item-alternatives: 14-1, 15-4, 19-4
Description: Commitment to new theories often involves a change in the meaning of familiar terms, the addition of new postulates, interest and attention directed to a new problem-field, a transformation of vision or gestalt-switch. A new theory which has attracted the commitment of the scientific community and replaced an older theory is frequently incompatible and incommensurable with its predecessor. Well

established theories function as dogmas in the sense of being taught as the core of established knowledge, of being the basis for judging the pertinence and scope of research problems, and of functioning as higher authorities in the attempted suppression of anomalous phenomena.

2B: Theories do not function as technical, specialized 'Weltanschauungen'.
α(scientists)=.53 α(philosophers)=.61
Item-alternatives: 14-4, 15-1, 15-2, 17-1, 17-2, 17-4, 19-2
Description: New theories are not usually incompatible with their predecessors. They do not usually direct attention to a new problem field or cause a transformation of vision. They do not define kinds of legitimate questions nor specify types of admissible solutions. They do not usually indicate fruitful mathematical or experimental techniques. They do not become the basis for judging the pertinence and scope of research problems.

Scale 3: Aim of science--theoretical
α(scientists)=.81 α(philosophers)=1.00
Item-alternatives: 4-2, 5-4
Description: The chief aim of science is to search for unity, pattern, and coherence in nature through the establishment of theoretical structures.

Scale 4: Aim of science--classificatory
α(scientists)=.75 α(philosophers)=.81
Item-alternatives: 4-3, 5-2
Description: The chief aim of science is to collect and categorize all laws and facts about natural phenomena.

Scale 5: Aim of science--social
α(scientists)=.82 α(philosophers)=.91
Item-alternatives: 4-4, 5-1
Description: The chief aim of science is to further the well-being of humanity or the means for leading better lives.

Scale 6: Scientific laws as empirical generalizations
α(scientists)=.57 α(philosophers)=.82
Item-alternatives: 6-2, 7-2
Description: Scientific laws are generalizations of relationships among natural phenomena supported by a vast body of consistent experience.

Scale 7: Scientific laws as confirmed theories
α(scientists)=.45 α(philosophers)=.82
Item-alternatives: 6-3, 7-3
Description: Scientific laws are theoretical explanations supported by much experimentation and observation.

Scale 8: Scientific laws as inviolable relations
α(scientists)=.67 α(philosophers)=1.00
Item-alternatives: 6-4, 7-1
Description: Scientific laws are absolutely certain reports of inviolable relationships.

Scale 9: Scientific models as analogies
α(scientists)=.71 α(philosophers)=.88
Item alternatives: 9-4, 10-3
Description: Scientific models are analogies which exhibit an identity of structure to some physical system, and together with a formalism constitute a theory.

Scale 10: Scientific models as roughly equivalent to theories
α(scientists)=.82 α(philosophers)=.98
Item-alternatives: 9-3, 10-4
Description: Scientific models and theories are roughly the same thing.

Scale 11: The relationship between the scientist and nature
α(scientists)=.74 α(philosophers)=.67
Composition: Scales 1 & 2

11A: Science as the process and product of a dynamic man-world interaction.
Description: Science is the process and product of a dynamic man-world interaction. Observation and theory formulation is not a passive state of information reception by the scientist, but an active process of describing, explaining and structuring what he judges he perceives. Scientific facts are not free of theoretical assumptions. Theories function as technical, specialized Weltanschauungen.

11B: Science as a literalistic description of nature.
Description: Scientific descriptions and accounts are literalistic, i.e. without analogic or symbolic character. The scientist's task is to reveal nature as it is in itself, to faithfully replicate nature as given, and to strive to achieve the single correct description of nature. New theories are not different Weltanschauungen, but corrections and additions to the edifice of knowledge.

Part 2

Scale 1: Progress in science
α(scientists)=.77 α(philosophers)=.92

1A: Fields of science evolve through periods of revolution and normalcy
α(scientists)=.62 α(philosophers)=.82
Item-alternatives: 9-2, 9-3, 10-2

Description: The development and evolution of the many fields of science has involved periods of revolution (when major disagreements and struggle over theory, methods, and types of legitimate questions and solutions occur) and periods of normalcy (when efforts are made to force nature into conceptual boxes and challenging problems are not seen). To describe the transition from one scientific tradition to another as 'revolutionary' means the scientific community underwent a complete restructuring of the way through which a portion of world was viewed.

1B: Fields of science do not evolve through periods of revolution and normalcy.
α(scientists)=.55 α(philosophers)=.81
Item-alternatives: 9-4, 10-4
Description: Progress and change in science cannot be characterized by periods of revolution and normalcy.

Scale 2: Objectivity in science
α(scientists)=.91 α(philosophers)=.98

2A: Objectivity as community-dependent mode of judging
α(scientists)=.73 α(philosophers)=.93
Item-alternatives: 1-4, 2-3, 3-2
Description: Objectivity in science is community-dependent, i.e. making objective judgments or decisions presumes a scientific community sharing a common set of assumptions and concepts, e.g. the selection of experiments largely depends on what problems the community is concerned about at the moment. Scientific objectivity consists of inter-subjective testability--the interperson checking and agreement between members of the scientific community. Factual 'hardness' is the degree to which the facts are a part of everyone's experience.

2B: Objectivity as community- and person-independent mode of judging.
α(scientists)=.80 α(philosophers)=.93
Item-alternatives: 1-1, 1-2, 1-3, 2-1, 2-4, 3-1.
Description: Scientific objectivity is community-independent and person-independent, i.e. objective judgments and decisions are impersonal, detached, disinterested, and free of subjective intrusions and concern. Science is objective because evaluation in science is not influenced by the interests and concerns of scientists, the scientist is indifferent about the conclusions and outcome of his research, scientists remove all bias from judgments made during their work, and the validity of scientific knowledge is independent of the scientific community.

Scale 3: Verification and falsification
α(scientists)=.78 α(philosophers)=.80

3A: Theories are not conclusively verified or falsified.
α(scientists)=.54 α(philosophers)=.61
Item-alternatives: 5-2, 6-2, 6-4, 7-2, 8-1
Description: It is meaningless to speak of 'proving' a scientific theory; all theoretical formulations are tentative and subject to revision; certainty is never achieved. A theory can be enforced or weakened by new data, but not proven or falsified. A theory is discarded when contradictory evidence is strong enough to erode confidence in the theory as a research guide and when an alternative theory exists which can account for the variant data. Theories are not conclusively proven or disproven because nature is statistical.

3B: Theories can be conclusively verified or falsified.
α(scientists)=.66 α(philosophers)=.92
Item-alternatives: 5-1, 5-3, 6-3, 7-1, 7-3
Description: Scientific theories can be conclusively proven either true or false. Much experimentation and observation proves the correctness of a true theory, although it may take a long time. Some theories are still doubted after they are proven true. Some theories are conclusively verified without recourse to experimentation or observation.

Scale 4: Theoretical transition, confirmation and the social dynamics of science
α(scientists)=.88 α(philosophers)=.95
Composition: Scales 1 & 2 & 3

4A: Science is characterized by the interaction of its cognitive structure with its communal self-consciousness and social dynamics, resulting in the production of 'confident' theories.
Description: The development and evolution of the theoretical structure of science has involved disagreement, struggle and competition between different schools of scientists. The theories that are continually confirmed by new evidence emerge and receive greater confidence. Together with the standards, purposes, and concerns of the scientific community, they define the bounds of scientific objectivity. Thus, science is characterized by the interaction of its cognitive (theoretical, confirmational) structure with the social dynamics of the historical scientific community.

4B: Science is characterized by the production of absolutely certain theories, and by the externality and independence of its cognitive structure from the community self-consciousness and social dynamics.

Description: The workings of the cognitive structure of science (including theorizing, proving, disproving, evaluating) are performed objectively, i.e. apart from and external to the biases, aspirations, and social conflicts of the community or its members. Scientists establish true, incontrovertible theories through impersonal, detached consciousness. There may be dispute until resolved by experimentation, but there is no revolution.